Digital Photogrammetric System

PHOTOMOD

Version 5.3

USER GUIDE

Processing of UAV data

RACURS

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1. Workflow of UAV data processing in the system

Processing of data acquired by pilotless vehicles (UAV) implies performing the following steps:

1. Creating UAV project.
2. Images block forming.
3. Interior orientation.
4. Import of exterior orientation parameters (if any).
5. Aerial triangulation, which includes the correct order of preset algorithm processing.
6. Block adjustment.

2. Create project

In order to create UAV project perform the following actions:

1. Choose active profile.
2. Run the system.
3. Open the **New project** window using one of the following ways:
   - choose **Project › Open/Manage**; click the **Create** button in the **Project management** window;
   - choose **Project › New**.

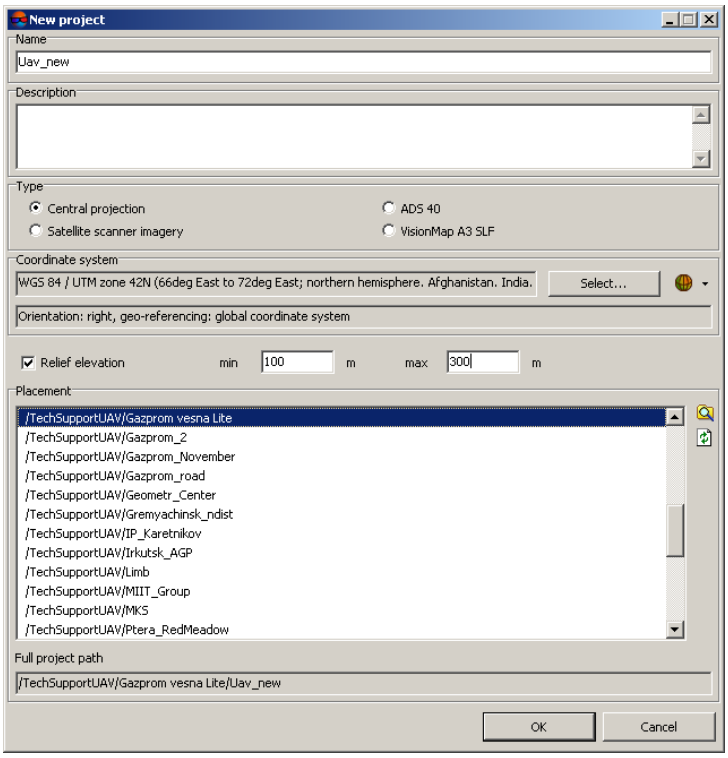


Fig. 1. Creation of UAV project

4. Input a new project name to the **Name** input field.

5. [optional] Input to the **Description** section a brief project description, its main features, notes etc.

6. Choose **Central projection** in the **Type** section.

7. Define a coordinate system using the **Select** button in the **Coordinate system** section.

8. Set the **Relief elevation** checkbox and specify at least approximately difference of terrain heights on project images in the **min** and **max** input fields.

   The relief elevation data is used to refine a block layout, it is considered during import of exterior orientation parameters and during calculation of ground sample distance (GSD).

   If the relief elevation data is unavailable or inaccurate by the time of project creation, the system allows to define the value later in the **Project properties** window (the **Project › Properties** menu item).

9. Choose a folder of active profile resources in the **Placement** list to place a project resources there. The **Full project path** input field shows a name and a path of a project.

10. Click OK to complete a project creation. Service folders and configuration files are created in specified project folder. The first strip used to add images is created automatically then.

See details about project creation in the “Project creation” User Manual.

3. Block forming

Prior to load UAV images to a project it is recommended to prepare them using the Raster Converter program as follows:

1. [if necessary] Perform radiometric correction.
2. Convert the images to files of inner *MS-TIFF* format.
3. Apply *JPEG compression with 85% quality* to output files.
4. Save files of modified images to *separate folder of active profile resources* (but not to the folder of a project).

See the Raster Converter program description in the “General information” User Manual.

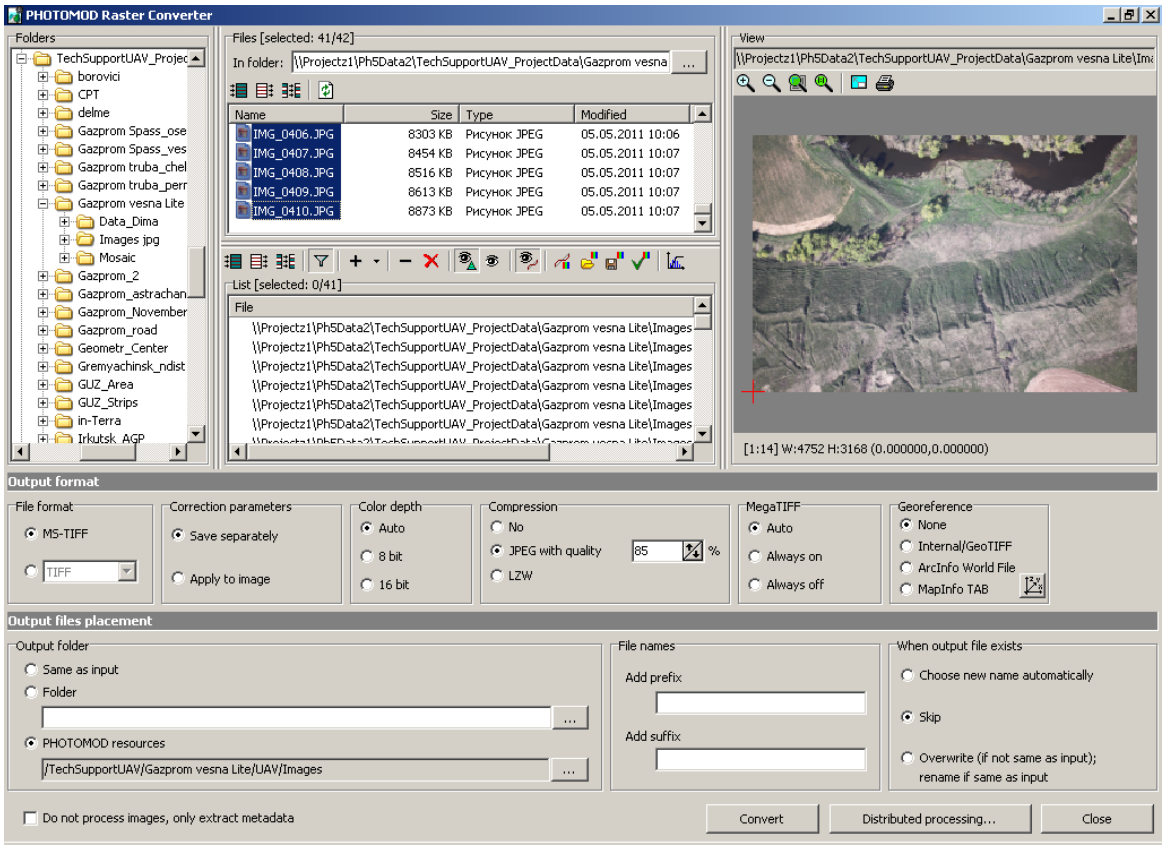


Fig. 2. Images conversion in the Raster Converter program

Perform the following actions to load images to a project and to form a block:

1. Choose **Window › Block editor** (for convenient work). The **Block editor** window opens.

2. Choose **Block › Add images from resources** or click the button in the **Block editor** window to start images adding. The **Open** window opens, allowing to display all active profile resources.

3. [optional] To filter showing files choose `Image in TIFF format` in the list rightward to the **Recourses name** field.

4. . Choose images files and click the **Open** button. After that all images are loaded to the first strip.

See a description of images load, setup and editing of images block in the “Project creation” User Manual.

4. Interior orientation

Interior orientation operation includes input or import of camera parameters, specifying of flight direction and angle of camera axes rotation for images of a project.

In order to implement interior orientation perform the following actions:

1. Choose **Orientation › Import orientation from metadata** to extract camera data from EXIF-metadata in images files. The **Import orientation from metadata** window opens.

2. Set the **Import interior orientation** and **Import exterior orientation** checkboxes (if EXIF-metadata contains exterior orientation parameters). Click OK.

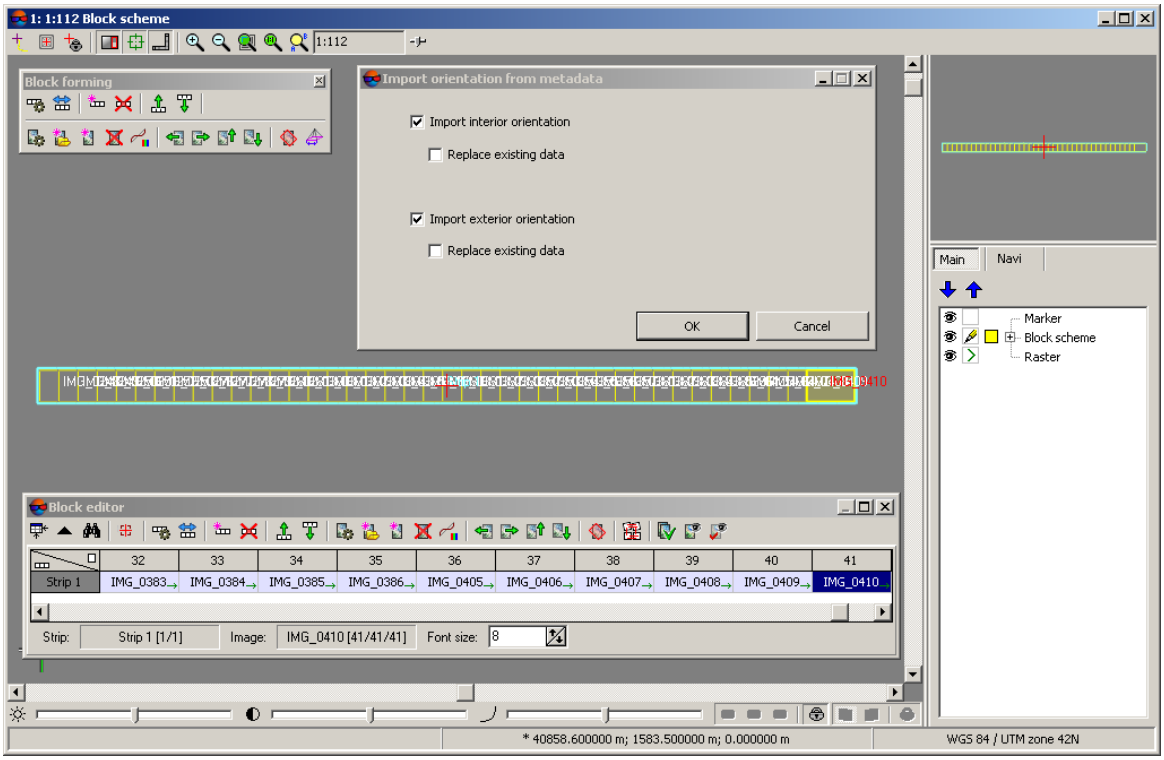


Fig. 3. Import orientation parameters from EXIF-metadata

3. Choose **Orientation › Manage cameras** to adjust camera parameters and define camera axes direction for project images. The **Manage project cameras** window opens.

4. Choose camera in the list and click the button. The **Camera** window opens and you can use it to view and edit camera data.

5. [optional] Input camera additional data (if camera passport is available) and click OK.

6. Specify flight direction using window of images preview and define camera axes rotation for project images in the following way:

    1. Choose images in the table which do not require axes rotation.

2. Set the **Set camera rotation for selected images** checkbox and specify a rotation angle so, that X axis coincides with flight direction.

3. Click the **Execute** button. Interior orientation is performed automatically.

See detailed description of interior orientation step in the “Aerial triangulation” User Manual.

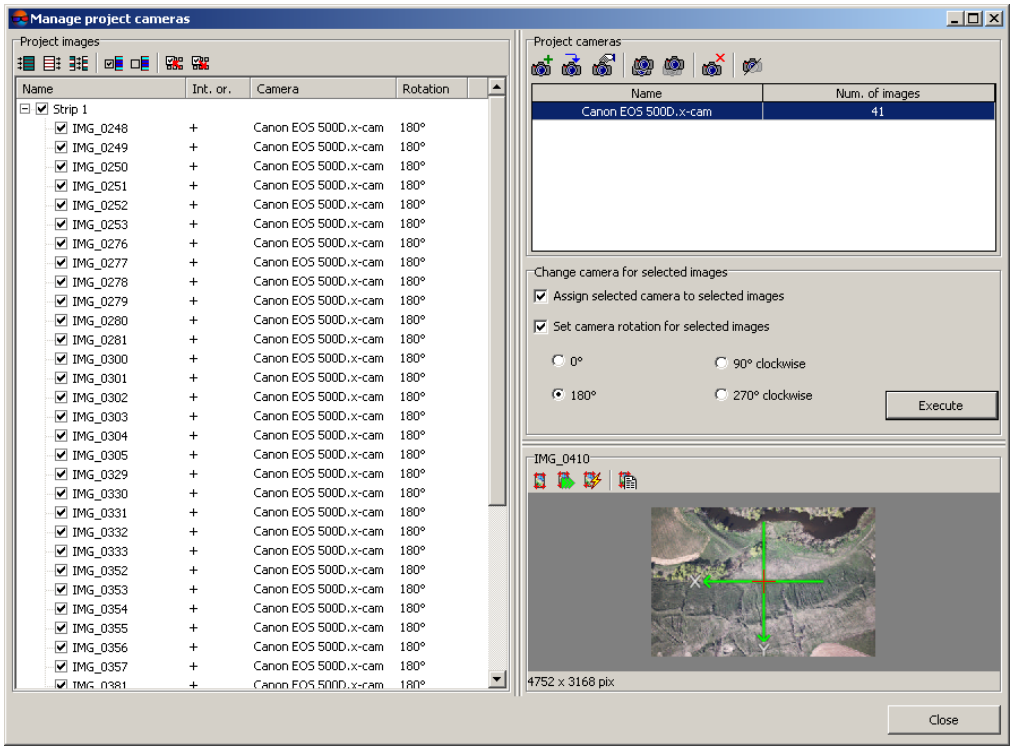

Manage project cameras
Project images
Name
Int. or.
Camera
Rotation
Strip 1
IMG_0248 + Canon EOS 500D.x-cam 180°
IMG_0249 + Canon EOS 500D.x-cam 180°
IMG_0250 + Canon EOS 500D.x-cam 180°
IMG_0251 + Canon EOS 500D.x-cam 180°
IMG_0252 + Canon EOS 500D.x-cam 180°
IMG_0253 + Canon EOS 500D.x-cam 180°
IMG_0276 + Canon EOS 500D.x-cam 180°
IMG_0277 + Canon EOS 500D.x-cam 180°
IMG_0278 + Canon EOS 500D.x-cam 180°
IMG_0279 + Canon EOS 500D.x-cam 180°
IMG_0280 + Canon EOS 500D.x-cam 180°
IMG_0281 + Canon EOS 500D.x-cam 180°
IMG_0300 + Canon EOS 500D.x-cam 180°
IMG_0301 + Canon EOS 500D.x-cam 180°
IMG_0302 + Canon EOS 500D.x-cam 180°
IMG_0303 + Canon EOS 500D.x-cam 180°
IMG_0304 + Canon EOS 500D.x-cam 180°
IMG_0305 + Canon EOS 500D.x-cam 180°
IMG_0329 + Canon EOS 500D.x-cam 180°
IMG_0330 + Canon EOS 500D.x-cam 180°
IMG_0331 + Canon EOS 500D.x-cam 180°
IMG_0332 + Canon EOS 500D.x-cam 180°
IMG_0333 + Canon EOS 500D.x-cam 180°
IMG_0352 + Canon EOS 500D.x-cam 180°
IMG_0353 + Canon EOS 500D.x-cam 180°
IMG_0354 + Canon EOS 500D.x-cam 180°
IMG_0355 + Canon EOS 500D.x-cam 180°
IMG_0356 + Canon EOS 500D.x-cam 180°
IMG_0357 + Canon EOS 500D.x-cam 180°
Project cameras
Name
Num. of images
Canon EOS 500D.x-cam
41
Change camera for selected images
Assign selected camera to selected images
Set camera rotation for selected images
0°
90° clockwise
180°
270° clockwise
Execute
IMG_0410
4752 x 3168 pix
Close

Fig. 4. The interior orientation window

5. Import of exterior orientation parameters

Exterior orientation parameters are *coordinates of projection centers and 3 angles*, that allow to specify in whole real position of images in space.

If exterior orientation parameters are available for UAV project, you can import them to the project. Exterior orientation parameters may be included to EXIF-metadata of images files or separately as a catalogue in a file of text format. You can find more about import of preliminary exterior orientation data from EXIF-metadata in Section 4.

In order to perform import of exterior orientation data catalogue from a file of text format, do the following:

1. Choose **Orientation › Exterior orientation data list** or click the button of the main toolbar. The **Exterior orientation parameters** window opens.

2. Click the button to import exterior orientation parameters.

3. Choose a file with exterior orientation parameters and click OK. The **Exterior orientation import – Step 1 of 2: File** window opens.

4. Setup a string template according to a type of data in columns of text file.

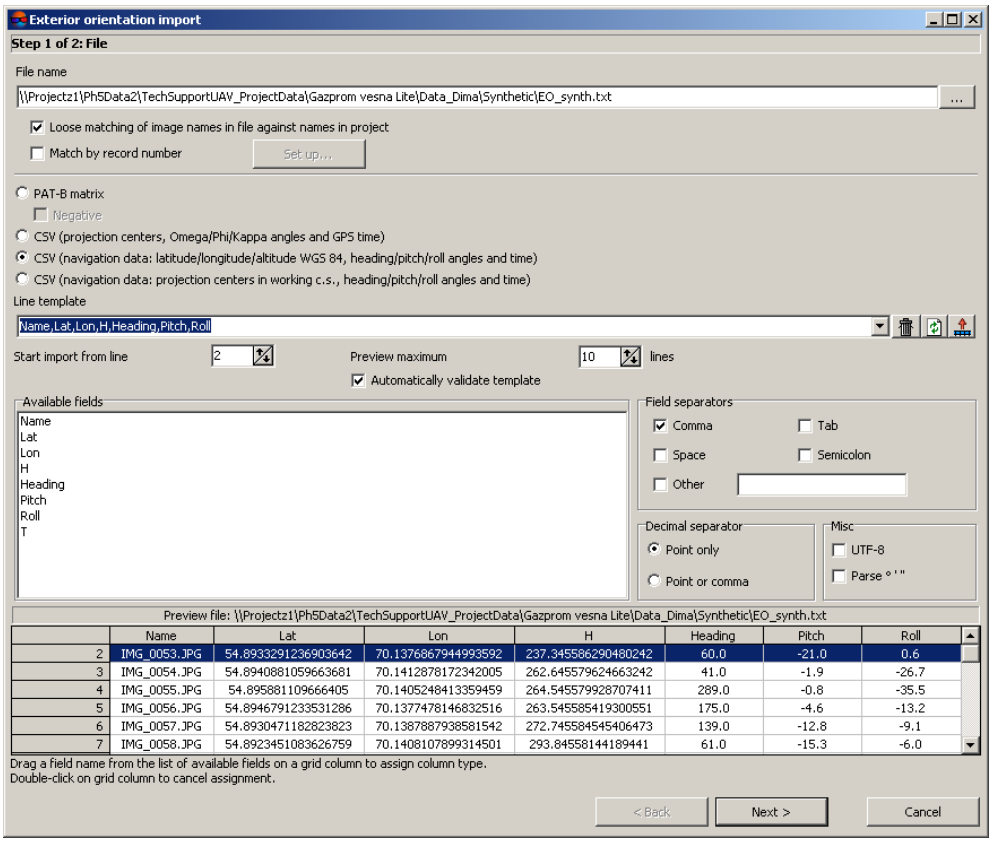


Fig. 5. Setup a file string template for import of exterior orientation parameters

5. Click the **Next** button. The **Exterior orientation import – Step 2 of 2: Import parameters** window opens.

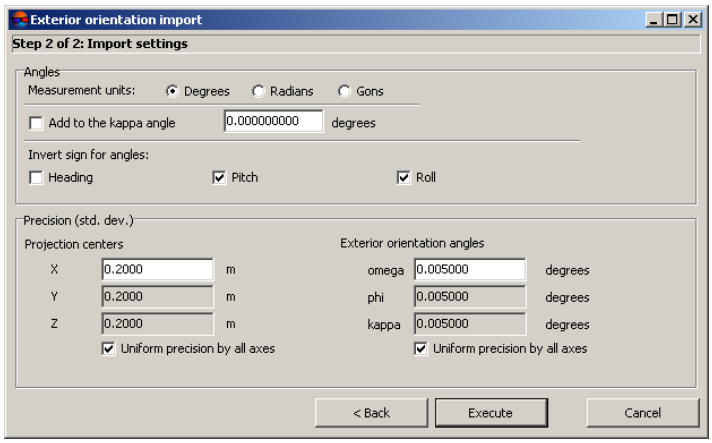


Fig. 6. Import options of exterior orientation parameters

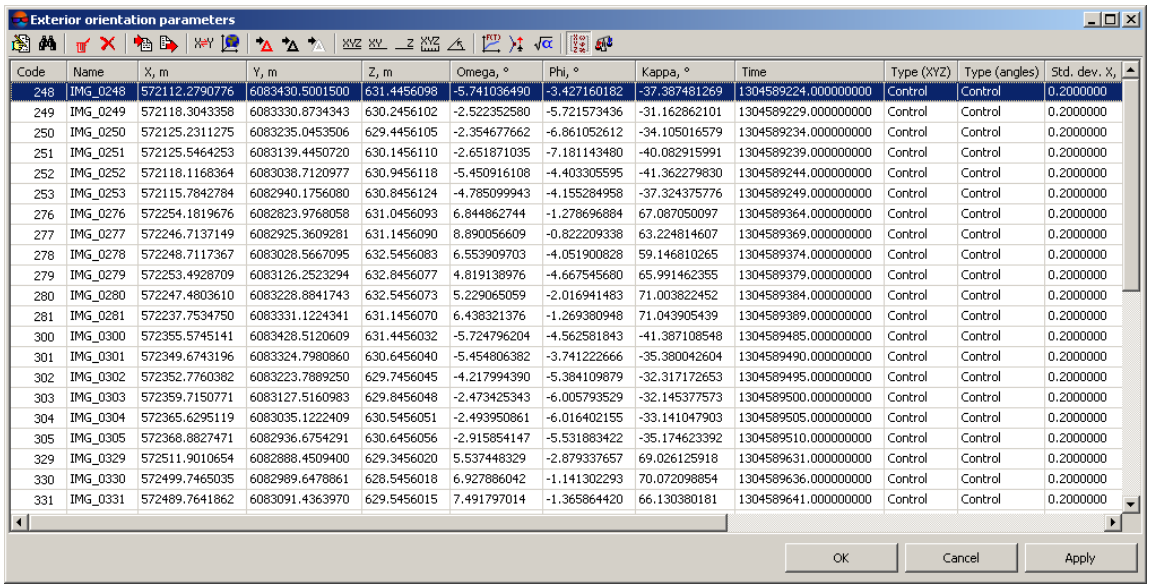
6. Define import parameters: units of angles measurements, sign character of angles in case of their incorrect defining by automatic pilot, as well as RMS of projection centers and exterior orientation angles.

   See a detailed description of string template setup and import options of exterior orientation parameters from text format file in the “Aerial triangulation” User Manual.

7. Click the **Execute** button to close the window and import exterior orientation parameters. Exterior orientation parameters obtained after the import are displayed in the table of the **Exterior orientation parameters** window.

8. Click the **Apply** button in the **Exterior orientation parameters** window to save exterior orientation parameters folder in the project.

9. Click OK to close the window and automatic re-build of the block scheme by exterior orientation (to build initial block layout).



Code	Name	X, m	Y, m	Z, m	Omega, °	Phi, °	Kappa, °	Time	Type (XYZ)	Type (angles)	Std. dev. X,
248	IMG_0248	572112.2790776	6083430.5001500	631.4456098	-5.741036490	-3.427160182	-37.387481269	1304589224.000000000	Control	Control	0.2000000
249	IMG_0249	572118.3043358	6083330.8734343	630.2456102	-2.522352580	-5.721573436	-31.162862101	1304589229.000000000	Control	Control	0.2000000
250	IMG_0250	572125.2311275	6083235.0453506	629.4456105	-2.354677662	-6.861052612	-34.105016579	1304589234.000000000	Control	Control	0.2000000
251	IMG_0251	572125.5464253	6083139.4450720	630.1456110	-2.651871035	-7.181143480	-40.082915991	1304589239.000000000	Control	Control	0.2000000
252	IMG_0252	572118.1168364	6083038.7120977	630.9456118	-5.450916108	-4.403305595	-41.362279830	1304589244.000000000	Control	Control	0.2000000
253	IMG_0253	572115.7842784	6082940.1756080	630.8456124	-4.785099943	-4.155284958	-37.324375776	1304589249.000000000	Control	Control	0.2000000
276	IMG_0276	572254.1819676	6082823.9768058	631.0456093	6.844862744	-1.278696884	67.087050097	1304589364.000000000	Control	Control	0.2000000
277	IMG_0277	572246.7137149	6082925.3609281	631.1456090	8.890056609	-0.822209338	63.224814607	1304589369.000000000	Control	Control	0.2000000
278	IMG_0278	572248.7117367	6083028.5667095	632.5456083	6.553909703	-4.051900828	59.146810265	1304589374.000000000	Control	Control	0.2000000
279	IMG_0279	572253.4928709	6083126.2523294	632.8456077	4.819138976	-4.667545680	65.991462355	1304589379.000000000	Control	Control	0.2000000
280	IMG_0280	572247.4803610	6083228.8841743	632.5456073	5.229065059	-2.016941483	71.003822452	1304589384.000000000	Control	Control	0.2000000
281	IMG_0281	572237.7534750	6083331.1224341	631.1456070	6.438321376	-1.269380948	71.043905439	1304589389.000000000	Control	Control	0.2000000
300	IMG_0300	572355.5745141	6083428.5120609	631.4456032	-5.724796204	-4.562581843	-41.387108548	1304589485.000000000	Control	Control	0.2000000
301	IMG_0301	572349.6743196	6083324.7980860	630.6456040	-5.454806382	-3.741222666	-35.380042604	1304589490.000000000	Control	Control	0.2000000
302	IMG_0302	572352.7760382	6083223.7889250	629.7456045	-4.217994390	-5.384109879	-32.317172653	1304589495.000000000	Control	Control	0.2000000
303	IMG_0303	572359.7150771	6083127.5160983	629.8456048	-2.473425343	-6.005793529	-32.145377573	1304589500.000000000	Control	Control	0.2000000
304	IMG_0304	572365.6295119	6083035.1222409	630.5456051	-2.493950861	-6.016402155	-33.141047903	1304589505.000000000	Control	Control	0.2000000
305	IMG_0305	572368.8827471	6082936.6754291	630.6456056	-2.915854147	-5.531883422	-35.174623392	1304589510.000000000	Control	Control	0.2000000
329	IMG_0329	572511.9010654	6082888.4509400	629.3456020	5.537448329	-2.879337657	69.026125918	1304589631.000000000	Control	Control	0.2000000
330	IMG_0330	572499.7465035	6082989.6478861	628.5456018	6.927886042	-1.141302293	70.072098854	1304589636.000000000	Control	Control	0.2000000
331	IMG_0331	572489.7641862	6083091.4363970	629.5456015	7.491797014	-1.365864420	66.130380181	1304589641.000000000	Control	Control	0.2000000

Fig. 7. Catalogue of exterior orientation parameters

In order to eliminate blunders in block scheme building by exterior orientation parameters, perform the following actions:

1. Refine block layout parameters, by performing the following actions:

    1. Click the button of the main toolbar. The **Block layout** window opens.

    2. Choose the **By ext. or.** mode and click the **Apply** button.

    See a description of block layout creation in the “Aerial triangulation” User Manual.

2. Import exterior orientation parameters from a file of text format once more and refine import parameters.

3. [optional] If course angle is measured not from central meridian, but from flight direction, perform the following actions:

    1. Choose **Block › Split into strips › By exterior orientation data**. The **Split into strips by exterior orientation** window opens.

    2. Specify move direction along strips and inside strips. Click OK.

    3. Click the button of the main toolbar. The **Exterior orientation parameters** window opens containing the catalogue of exterior orientation parameters.

    4. Click the button to set kappa angle in the direction of trajectory for all or for selected images. Click OK.

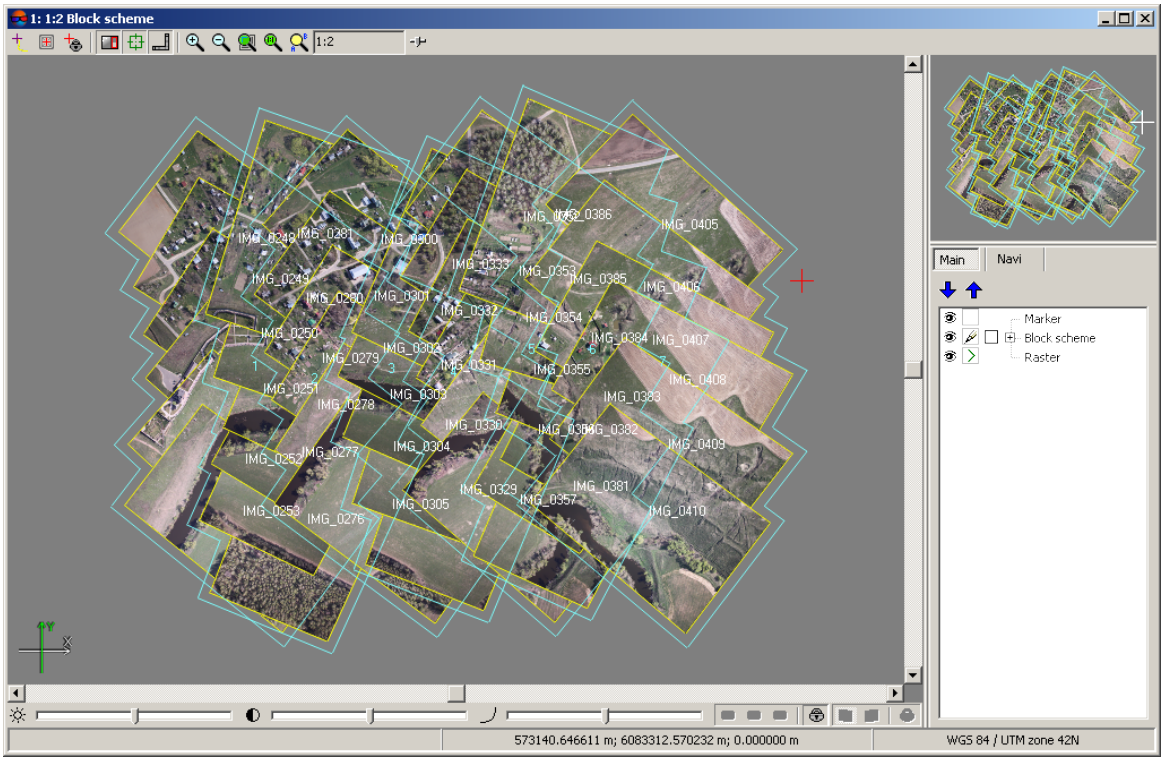


Fig. 8. Example of incorrect block scheme, when a course angle is not measured from central meridian

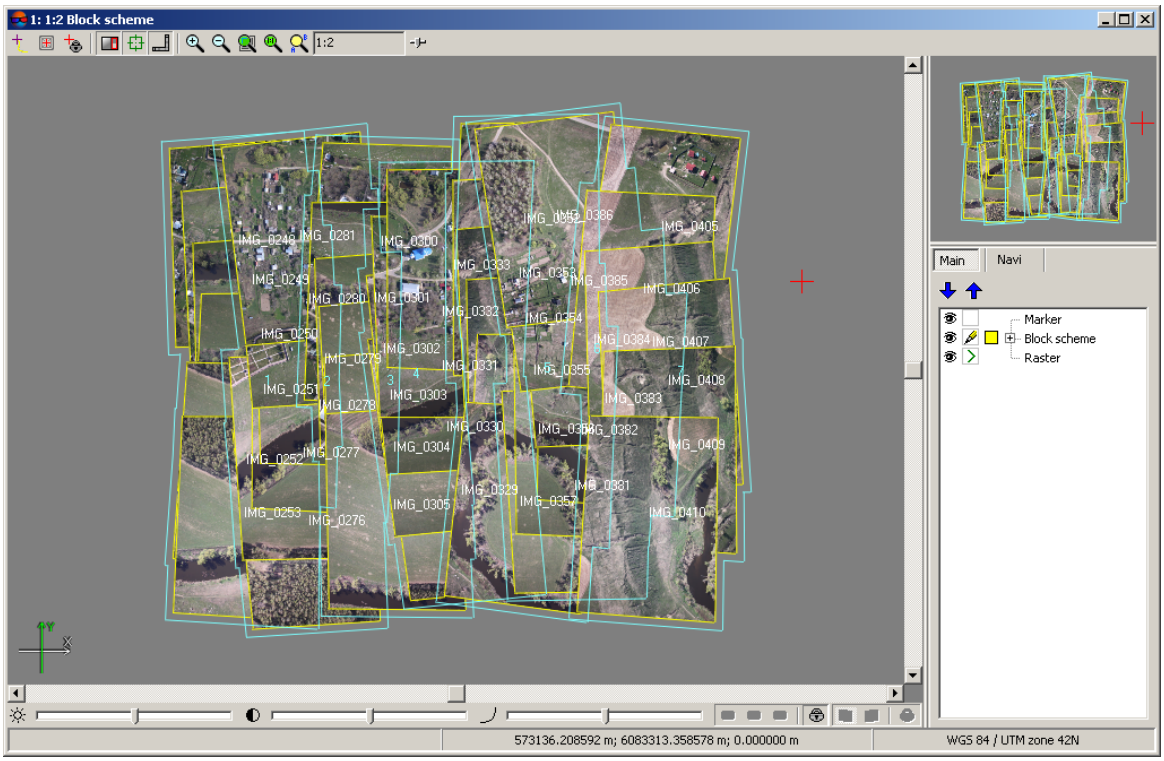


Fig. 9. Block scheme after kappa angle is set in the direction of trajectory

Block scheme, created using exterior orientation is an initial block layout and requires further refining by tie/GC points (see Section 6).

6. Aerial triangulation

On aerial triangulation step you can perform tie points measurement in automatic mode and relative orientation, as well as GC point measurement (if coordinates are available).

For automatic *tie points* coordinates measurement and relative orientation, perform the following actions:

1. Execute automatic UAV triangulation to refine initial block scheme.
2. Perform automatic measurement of tie points using build-in set of parameters for UAV.

For automatic UAV triangulation do the following:

1. Choose **Orientation › Automatic UAV triangulation**. The **UAV automatic triangulation** window opens.

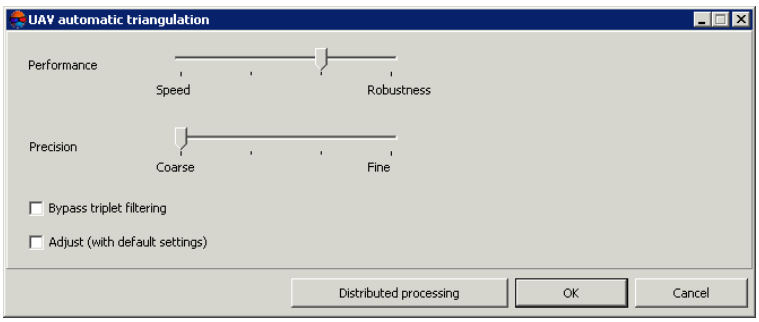


Fig. 10. Settings of the UAV automatic triangulation

2. Set the following options of the UAV automatic triangulation:
   - **Perfomance** – choose **Speed** for less points and higher speed or choose **Robustness** for more points and less speed;
   - **Precision** – choose **Coarse** to increase of the parallax allowance or choose **Fine** for better precision and less allowance;
   - **Bypass triplet filtering** – set this checkbox not to filter points in the triple overlapping;
   - **Adjust (with default settings)** – set this checkbox to adjust the block after the UAV automatic triangulation.

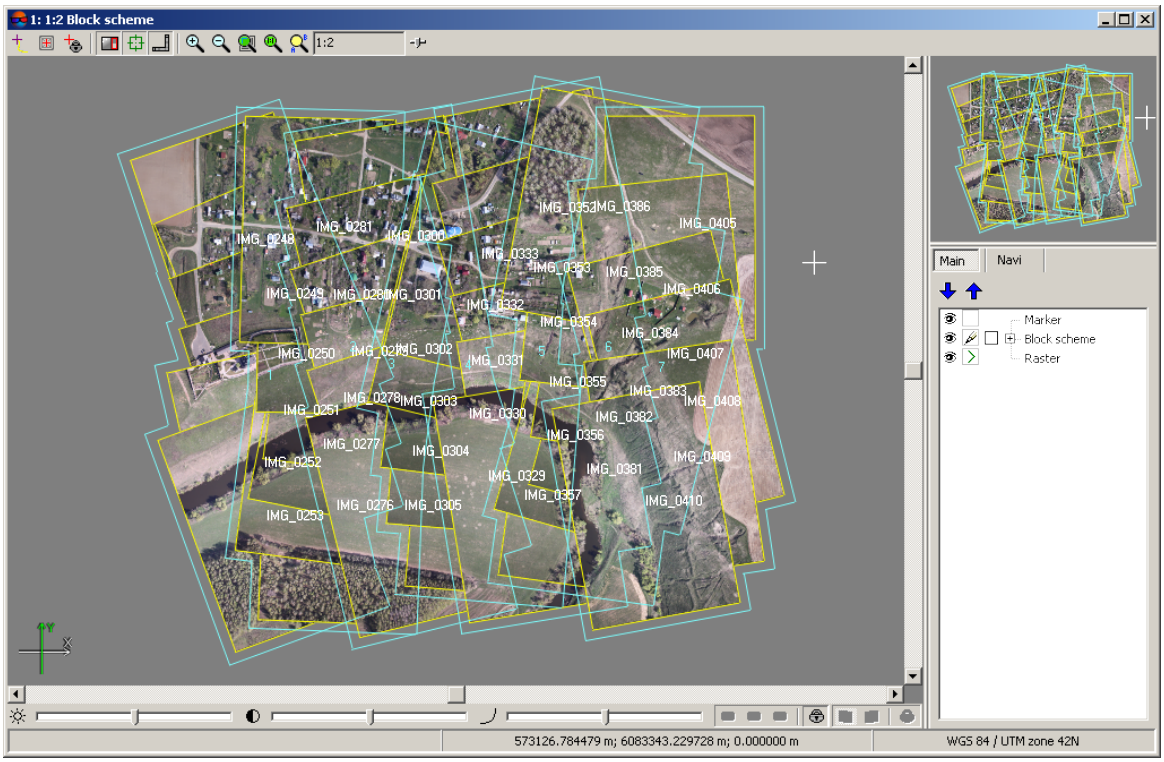


Fig. 11. Block scheme after automatic UAV triangulation

3. Click OK for automatic UAV triangulation in normal mode.

   To distribute the triangulation process do the following:

   1. Change settings and run the distributed processing server/client (see the "*Distributed processing*" chapter in the "General information about system" User Manual).

   2. Press the button in the **Tasks** part of the **Monitor for distributed processing** to start tasks automatically after theirs creating.

   3. Click the **Distributed processing** button. The **Distributed processing parameters** window opens.

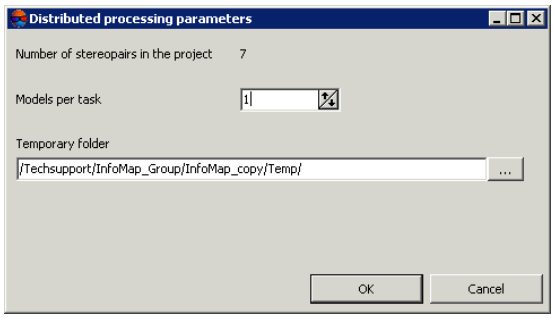


Fig. 12. Distributed processing parameters of the UAV automatic triangulation

The number of stereopairs in the project shows automatically in the window.

4. Define the number of **Models per task** so as one task uses one kernel.

5. In the **Temporary folder** field select an empty folder for temporary data.

   Folder must be available on the all utilized workstations.

6. Click OK. Distributed processing tasks are creating and information about number of tasks is shown on the screen.

   If the **Auto run tasks** mode doesn't in the **Monitor for distributed processing** window, processing will not start.

4. Choose **Orientation › Report on relative orientation** or click the button to evaluate initial triangulation in relative orientation report. Residuals of UAV triangulation are considered during setting parameters of automatic tie points measurement.

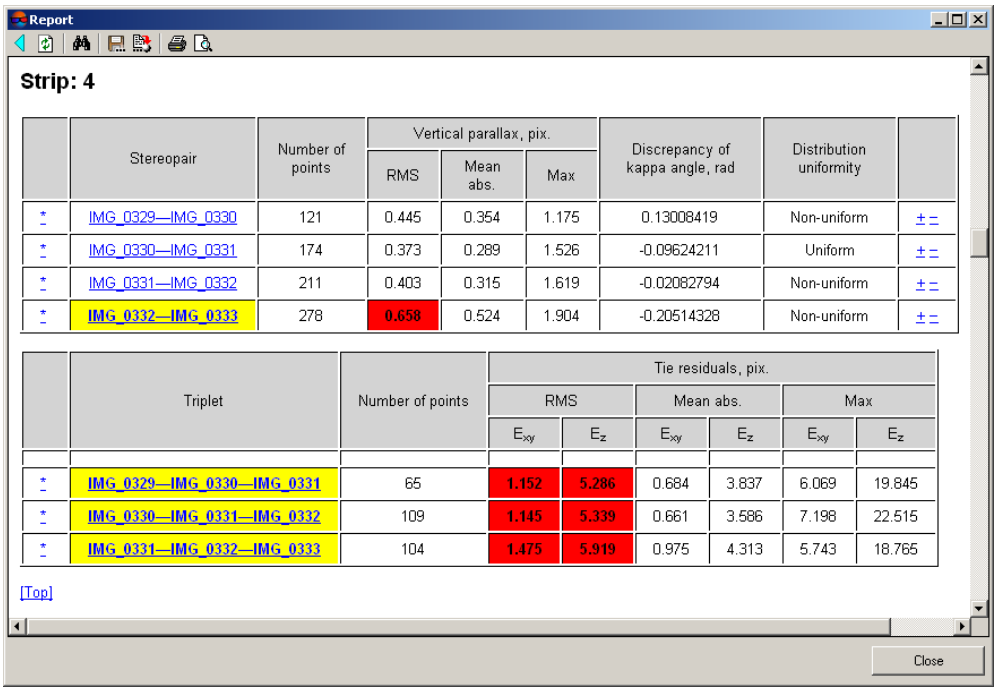


Fig. 13. Evaluation of residuals of automatic UAV triangulation

For automatic tie points measurement with UAV preset perform the following actions:

1. Choose **Orientation › Automatic tie points measurement** or click the button. The **Automatic tie points measurement** window opens and you can use it to setup of points measurement parameters.

2. Setup main and additional parameters for automatic tie points measurement considering the following recommendations:

   - As a base parameters set for tie points measurement for UAV projects it is recommended to use a pre-set UAV parameters set, that ensures satisfying result even with poor quality images. To load a set of UAV parameters click the arrow next to the button to open drop-down menu and choose **UAV**.

     See detailed description of main and additional parameters of automatic tie points measurement in the “Aerial triangulation” User Manual.

   - You should remember that each flight is unique, uses different UAV, cameras, on-board GPS/IMU with different accuracies. That is why output images have different quality and spatial geometry. Thus, you should setup parameters of automatic measurement considering particular project features.

3. Choose **Orientation › Report on relative orientation** or click the button to analyse and correct measurements errors in relative orientation report.

4. [optional] Repeat steps 2-3 if necessary, picking optimal parameters of tie points measurement and verifying measurement results using relative orientation report.

For example, for images of good quality you can set more “rigid” parameters and start automatic tie points measurement twice: first to measure the points inside strips, then – between strips.

The example below shows a set of images of good quality, so more “rigid” parameters were set and automatic tie points measurement was performed twice: first to measure the points inside strips, then – between strips.

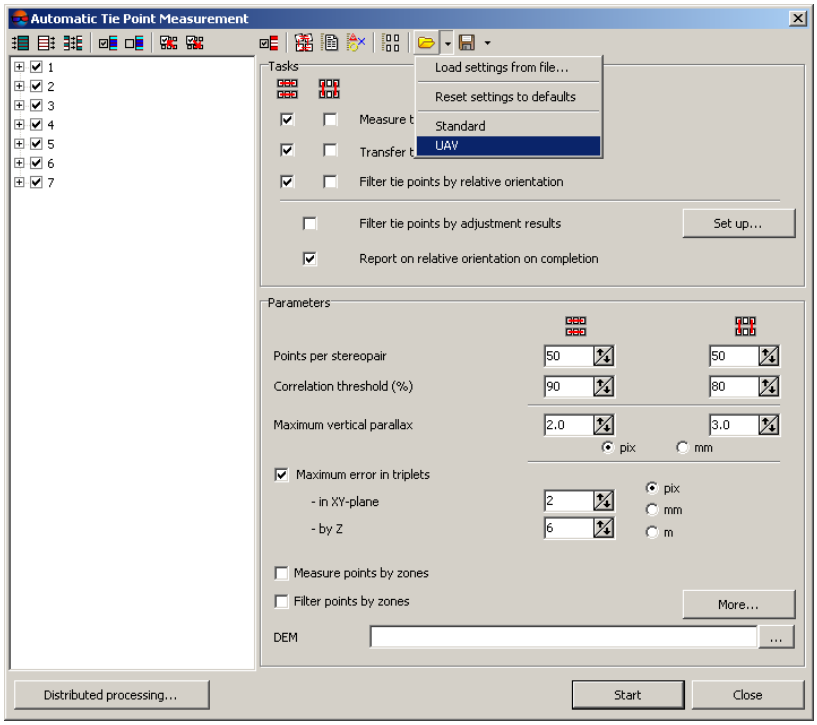


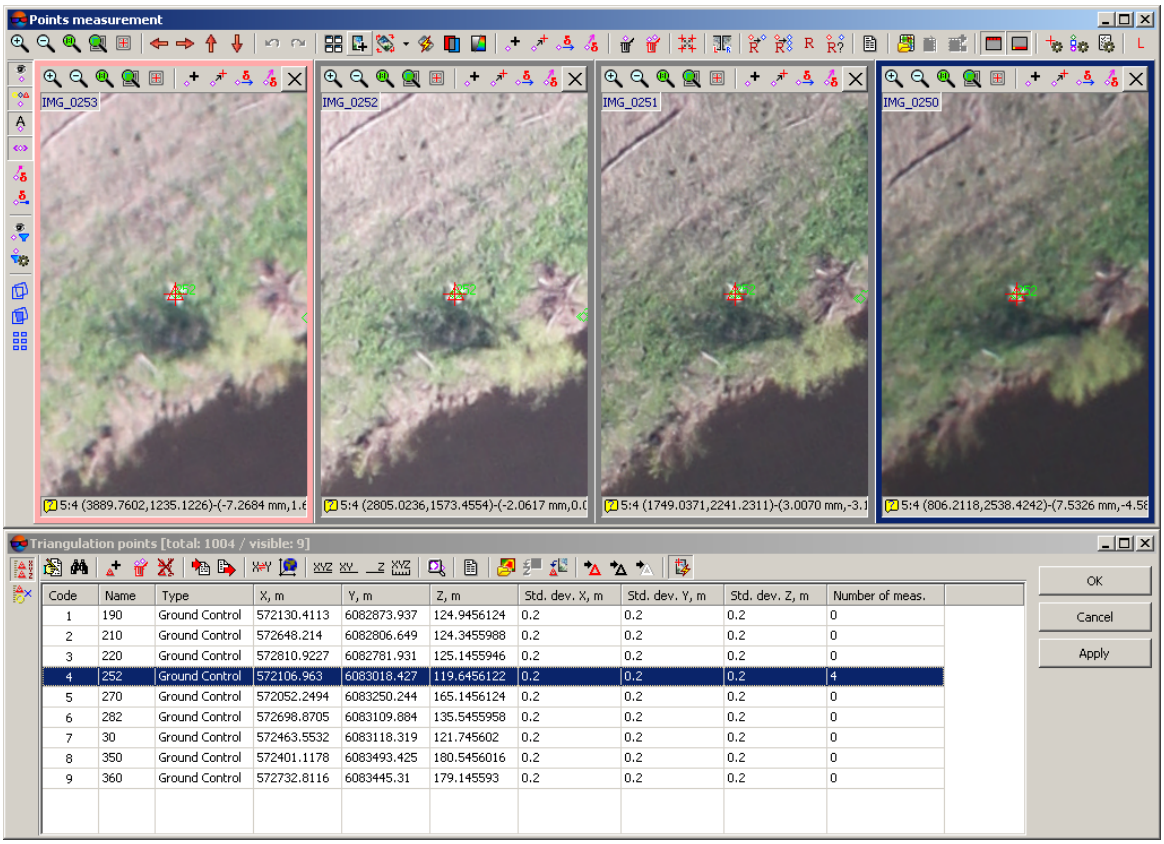
Fig. 14. Example of parameters set for automatic tie points measurement for UAV project

In order to measure *GCP* perform the following actions:

1. Choose **Orientation › GCP list** or click the button to input GCP coordinates manually or to import GCP coordinates catalogue from file of text format.

2. Measure GCP on project images in the **Points measurement** module.

See details about input/import/measurement of GCP in the “Aerial triangulation” User Manual.



Code	Name	Type	X, m	Y, m	Z, m	Std. dev. X, m	Std. dev. Y, m	Std. dev. Z, m	Number of meas.
1	190	Ground Control	572130.4113	6082873.937	124.9456124	0.2	0.2	0.2	0
2	210	Ground Control	572648.214	6082806.649	124.3455988	0.2	0.2	0.2	0
3	220	Ground Control	572810.9227	6082781.931	125.1455946	0.2	0.2	0.2	0
4	252	Ground Control	572106.963	6083018.427	119.6456122	0.2	0.2	0.2	4
5	270	Ground Control	572052.2494	6083250.244	165.1456124	0.2	0.2	0.2	0
6	282	Ground Control	572698.8705	6083109.884	135.5455958	0.2	0.2	0.2	0
7	30	Ground Control	572463.5532	6083118.319	121.745602	0.2	0.2	0.2	0
8	350	Ground Control	572401.1178	6083493.425	180.5456016	0.2	0.2	0.2	0
9	360	Ground Control	572732.8116	6083445.31	179.145593	0.2	0.2	0.2	0

Fig. 15. GCP measurement in the **Points measurement** module

7. Block adjustment

In order to adjust images block perform the following actions:

1. Click the button of the main toolbar to refresh initial block scheme (to refine block layout) using measured tie and GC points.

   See description of block scheme creation in the “Aerial triangulation” User Manual.

2. Choose **Orientation › Block adjustment** or click the button of the main toolbar to launch adjustment module. The main window of the **Block adjustment** module opens and displays data collected during aerial triangulation step.

   See detailed description of work in the adjustment module in the “Block adjustment” User Manual.

3. Click the **Parameters** button of the main module toolbar. The **Parameters** window opens.

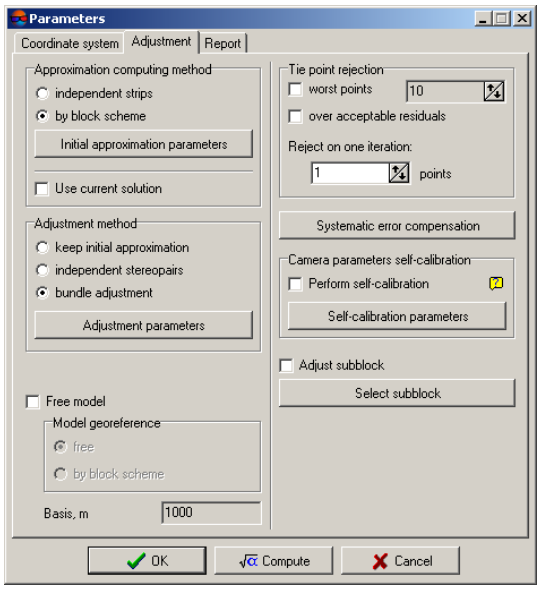


Fig. 16. Adjustment parameters for the first adjustment operation

4. On the **Adjustment** tab define the following parameters *for the first* start of the adjustment procedure:

    1. Choose the **by block scheme** option in the **Approximation computing method** section.

    2. Click the **Initial approximation parameters** button. The **Independent strips adjustment parameters** window opens.

    3. Set the **Use ground control points coordinates** and **Use projection centers coordinates** checkboxes.

    4. Click OK.

    5. Choose the **bundle adjustment** option in the **Adjustment method** section.

    6. Click the **Adjustment parameters** button. The **Bundle adjustment parameters** window opens.

    7. Set the **Use ground control points coordinates** and **Use projection centers coordinates** checkboxes.

    8. Choose the **in 3D space** option in the **Minimize residuals** section.

    9. Click OK to return for the **Parameters** window.

5. Click **Compute** to start the adjustment operation.

6. To analyse the adjustment results you can use visual control of residuals on block scheme displayed on the **Stereopairs** and **Images** tabs, brief residuals report (the button) or detailed report on block adjustment (the **Report** button).

7. Pick out adjustment parameters, analyse and eliminate residuals to obtain satisfying adjustment result.

   After making any alterations to points measurements data during work in the **Block adjustment** module you should re-start the adjustment procedure once again.

   If you are going to use previous adjustment results for the new adjustment operation, set the **Use current solution** checkbox on the **Adjustment** tab of the **Parameters** window.

8. [optional] If a complete set of camera parameters is unavailable, use self-calibration of camera parameters during adjustment procedure.

   Self-calibration of camera parameters – is automatic calculation of camera parameters (corrections to principal point coordinates, focal length and distortion coefficients) during adjustment procedure.

   In order to execute self-calibration of camera parameters during adjustment operation perform the following actions:

   1. Set the **Perform self-calibration** checkbox and click the **Self-calibration parameters** button on the **Adjustment** tab of the **Parameters** window. The **Camera parameters self-calibration** window opens.

      See detailed description of self-calibration operation in the “Block adjustment” User Manual.

   2. Choose camera to be calibrated in the **Cameras** table. In the **Coefficients** table define initial values of camera parameters in the **Initial value** column and choose parameters for optimization in the **Optimize** column.

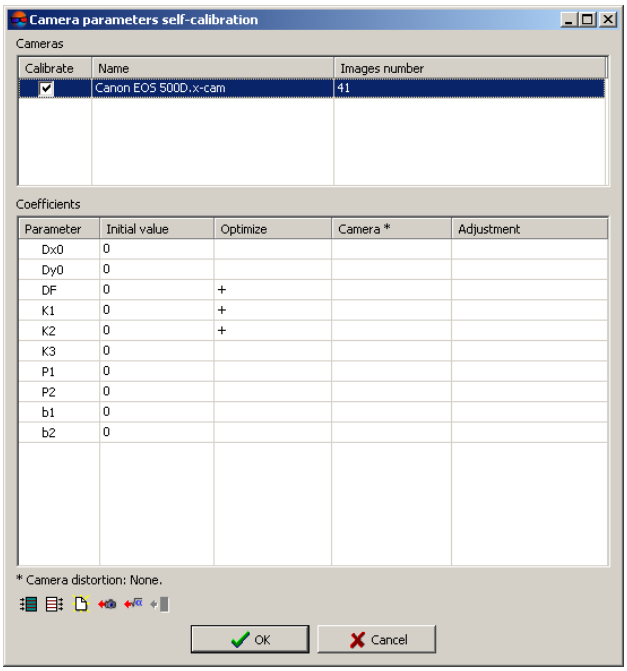


Fig. 17. Self-calibration of camera parameters

3. Click OK. Setup adjustment parameters in the **Parameters** window and click the **Compute** button to start the adjustment procedure.

4. After adjustment operation is complete estimate the adjustment accuracy and camera self-calibration results, shown in the **Adjustment** column of the **Camera parameters self-calibration** window. If you are satisfied with the results pass to step # 5, otherwise, change initial values of parameters and/or set of parameters for optimization and adjust the block once more.

5. Click the **Save** button to save the adjustment results. Close the adjustment module.

When exiting from adjustment module the **Perform self-calibration** checkbox on the **Adjustment** tab of the **Parameters** window is cleared automatically.

6. Choose **Orientation › Manage cameras**. The **Manage project cameras** window opens.

7. In the **Project cameras** list choose new calibrated camera (cameras) `[autocal].x-cam` and assign it (them) to project images. Click the **Execute** button. Click OK.

See a description of the **Manage project cameras** window in the “Aerial triangulation” User Manual.

8. Choose **Orientation › Interior orientation › Calculate interior orientation**.

9. Choose **Orientation › Block adjustment** or click the button of the main toolbar to run the adjustment module once more. Click the **Compute** button. The block is adjusted considering new results of interior orientation.